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THE SYMBIOSIS OF STOCK AND GRAFT.

BY ERWIN F. SMITH.

Under the title, Ueber Transplantation am Pflanzenkörper, (pp. VI, 162, Pl. XI, figs. 14), Dr. Hermann Vöchting, Prof. of botany in the University of Tübingen, has contributed a study on the relations of graft and stock which is of unusual interest. After some consideration of the literature of the subject he discusses (1) Methods of grafting, (a) Grafting of like parts in normal and abnormal positions; (b) Grafting of unlike parts; (2) The symbiosis of scion and stock; (3) Histological investigations. The author's conclusions relative to the mutual relations of stock and graft rest upon careful experiments covering a period of some years. His first experiments consisted in the union of parts of the same and related varieties of the red beet. The top of a plant recently grown from the seed but sufficiently large was cut away and young shoots from two-year old blossoming plants were grafted on. These cions were taken from the base of recently developed shoots and bore from two to three vegetative buds. These buds grew into short, fleshy sprouts plentifully provided with leaves which resembled those of the *first year*, i. e. were not like those on the blossom shoot from which they were taken. Subsequently the axis also became thickened but to a less degree. The shoots did not produce blossoms but elaborated food for

their own use and that of the root. The roots also increased in circumference in proportion to the amount of their nourishment. This growth was excentric and preponderatingly under the cion. The following year blossoms were produced in the ordinary manner and death followed. *Conclusion:* If these shoots had remained on the parent plant, they would have blossomed the same season and died in the fall. Inserting them on the young root changed them into a vegetative state and prolonged their life for a whole year. In this case the young root exerted the controlling influence. In another experiment plants at the commencement of the second year were divided into two lots. The plants of one set were forced into a rapid development of blossoms; the others were restrained from blossoming by being kept in a cool place. The tops of the retarded plants were cut away and cions from the forced plants were inserted. The result of this experiment was quite different. These cions developed blossoms in the normal way. None of them remained short or formed the tufts of broad leaves which were peculiar to the sprouts in the previous experiment. In this case the leaves had long petioles and rather narrow blades as in ordinary blossom shoots. Here likewise the roots increased in size near the inserts, i. e. around them and below. *Conclusion:* Grafting on young and old roots leads to very different results.

Knight's law, expressed still more clearly by van Mons, that only its own nature controls the development of the cion, is not universally true. Cion and stock mutually influence each other always. Sometimes one preponderates in influence, sometimes the other. The control exercised by the stock in these experiments with the beets is ascribed to movement of assimilative matters (stoffwechsel). The young root grows and stores up reserve materials, chiefly sugar. The old root does not grow, gives up its reserve materials, and dies after it is emptied. "It is plain," says the author, "that the manner of growth of the bud, i. e. its development into a vegetative or floral shoot, depends less upon itself than upon the parts bearing reserve substances, especially the roots."

In the middle of June, segments were removed from old roots, then producing blossoms, and were inserted into young, actively-growing roots, only recently developed from the seed. There was union of tissues but no increase in circumference, no radial growth. When these inserted pieces were examined the following winter they were, unexpectedly, found full of sugar. The cells bore abundant plasma, fine nuclei, and seemed to be in good condition, although at the time of their insertion they had given up the greater part of their reserve materials. The only possible conclusion is that the root inserts had formed new cane sugar out of the materials brought to them by the young roots. Old beets were set into young roots and in this way also their life was prolonged, the old parts dying only a little earlier than the young roots. In this case they showed no such quantity of sugar. Inasmuch as these old roots did not increase in thickness in spite of their good nourishment by the young roots it might be inferred that they are not capable of it, but such an inference would be wrong. Segments of old roots taken in the middle of March and inserted into the basal parts of panicles in rapid development showed a marked growth, what the author calls,—"ein sehr auffallendes Verhalten." They began a new process of development, grew up above the surface of the stem on a level with which they were originally inserted, and ended by forming swellings of various sizes and shapes. When the piece of root was inserted upside down it was swollen at the upper end, when it was inserted right end up the swelling was at the lower end. The stem around the insert also finally enlarged, sometimes only above the insert, sometimes also at both sides. The growth of these root-inserts was very remarkable. Under normal conditions the same pieces would have made no growth whatever. Planted in the blossoming stem they began to grow, and this growth was so energetic in some cases that the pieces increased to several times their original volume. Dr. Vöchting is in doubt as to the cause of this behavior, but concludes from it that there is no necessary relation between growth and the storing of sugar since he found these growths very poor in sugar although the cells appeared to be active.

Some attempts were made to unite annuals and perennials. The tomato was used for a stock, the author not being aware, apparently, that the tomato is not strictly annual but frequently lives far into the second year and even longer in green houses and in warm climates. In the first series of experiments cions of *Solanum dulcamara* were grafted on. They made a good union and more growth than any shoots on the parent stem. In the fall the plants were removed to a house. Gradually the leaves fell off, but the sprouts remained fresh for a time. They died, however, in December or January, the disturbance beginning below with the stock. It was thought that owing possibly to the fall of the leaves and the cessation of the activity of the graft, it had not sufficiently stimulated the stock, so another experiment was made using as cions Solanum capsicum and S. *pseudocapsicum*, which hold their leaves over winter. A good union was secured and the plants developed fine tops and prospered until winter. In early winter the stocks became diseased at the root and the tops died quickly. One plant, however, held on longer and toward the end of December the part of the stock above ground formed adventive roots. In January the graft turned yellow and died. *Conclusion:* These experiments do not show that the life of annuals can be prolonged by grafting perennials upon them but it is not certain that such an end might not be reached by the use of other plants. An experiment was also made on *Mercurialis annua* which bears staminate and pistillate flowers on different plants. Portions of male and female plants were united by grafting but the result was negative, the sex remaining distinct. Mention is also made of a staminate Ginkgo tree in the Botanical Garden at Basle into which a pistillate branch was grafted many years ago. This has grown into a stately system of branches but the sexual parts are just as distinct as on separate trees. The same result has been reached in the same garden with *Acuba japonica.*

Plants of varied color and form were also grafted together. The more recent discussion of the symbiosis of cion and stock turns chiefly on the subject of the transmissibility of panachure and on the possibility of graft hybrids. A portion of the

white and yellow spotting of variegated leaves is unquestionably pathological and is readily transmitted by grafting. Since we do not know the cause of this disease, we can form no definite idea as to its method of transmission, yet the whole process of transmission gives the impression of an infection. How this takes place we do not know, but it seems as if it must be through the wandering of specific material particles out of the variegated cion into the stock. Concerning the transmission of non-pathological peculiarities such as colors, especially those held in the cell sap, the author thinks that they cannot pass directly into the stock, but that something must pass that is able to produce them. He saw in Bonn, Lindemuth's experiment in which violet color was transmitted from a potato cion to the green stock, and says it was so. His own experiments are as follows: *Coleus.* Many experiments with characteristic forms. The unions were easily affected and the plants were kept into the second year and some into the third year. *Conclusion:* In no case was there any transmission of color from the graft to the stock, or from the stock to the graft. Neither was there any influence on the form or nervation of the leaves. Cion and stock retained their original peculiarities unchanged. *Tradescantia:* The shoots of *T. zebrina* and *T. quadricolor* were grafted on the green *T. Sellowi.* The cions reached a considerable length but in no case was there any transmission of color. *Beets* (salad, fodder, and sugar): (a) *Union of different colored beets.* Dr. A. Maclean of Colchester, England, was the first to try this in 1853. He joined the root of a red beet to that of a white Silesian beet. They united but the red part remained sharply delimited from the white. There was no transmission of color or of form. In the author's own experiments white and orange, white and red of various shades, and yellow and light and dark red beets were united. In part of the experiments roots were joined to roots; in others shoots, to roots. With one exception there was no transmission of color from cion to stock or vice versa. Each part retained its own color. The blending of colors did not occur even in the region of the union. Microscopic examinations were made and the place of union

could be seen very distinctly. The exception was as follows: The shoot of a red beet was worked on the root of a white mangel wurzel? (Futterrübe) and subsequently a red color appeared in the swelling around the inserted cion. No such color was visible on the rest of the root, nor could any such be found on other ungrafted roots of this variety. It would seem that the color in this root was due to the influence of the graft and that this experiment supports Lindemuth's observations. Nevertheless this case is not entirely beyond suspicion since colored beets are apt to develop most color in the vicinity of wounds, and because all varieties of beets are nearly related and though apparently constant may possess latent peculiarities. (b) *Union of bodies of different sizes.* Very large white beets were grafted on small dark red ones and vice versa, the parts being about the same size when united. In the first case the plants grew more than in the second, i. e. because they had a larger leaf surface for assimilation. (c) *Union of varieties having unlike shapes.* Each grew after its own manner uninfluenced by the other. M. Gaillard tried grafting Cucurbitaceous plants and got the same result. White, green and yellow colocynths were united but there was no blending of colors.

Several attempts were made to procure graft-hybrids. The author wholly failed to get variegated hyacinth flowers by a union of different bulbs. Even when the union took place between blossom stalks there was no mixture. In experiments with potatoes his results confirm Lindemuth's. There was no mixture. Many experiments were tried using well marked and constant varieties very distinct in color and form. He discarded the tubers and worked with young, well-rooted shoots which were removed from the tubers, set out in the earth, and grafted as soon as they were a short distance above the ground. As soon as the cions were healed on, the plants were put into a hot bed. They remained here until the fall of the leaves in autumn, care being taken to remove all the green leaves which appeared from time to time on the stock so that it should be nourished only by the vegetation of the cion. At the close of the experiment the tubers were found to possess all of the peculiarities of the mother plant. The cions did not

produce any change either in color or form. In Strasburger's experiment of grafting Datura on potato and getting atropin in the tubers, if the malformation of part of these tubers was due to the presence of atropin then it is a case of poisoning and not of a change in the specific nature of the stock due to the cion, as Strasburger also admits. From the observations of Lindemuth there can be no doubt that many of the reports of graft hybrids rest on errors. Master's reported an experiment made by Maule of Bristol and exhibited a photograph showing *Helianthus tuberosus* grafted on *H. annuus* and the roots of the latter bearing tuberous growths. This experiment was repeated by M. Carriere, a very careful observer, and on the roots of his *Helianthus annuus* appeared two budless black swellings with a rifted surface, and in general resembling certain dahlia tubers. In the vicinity of these were other forms which more nearly resembled the artichoke. This experiment should be repeated. *Conclusion:* Either there are no such things as graft hybrids or else they are limited to a small number of plants.